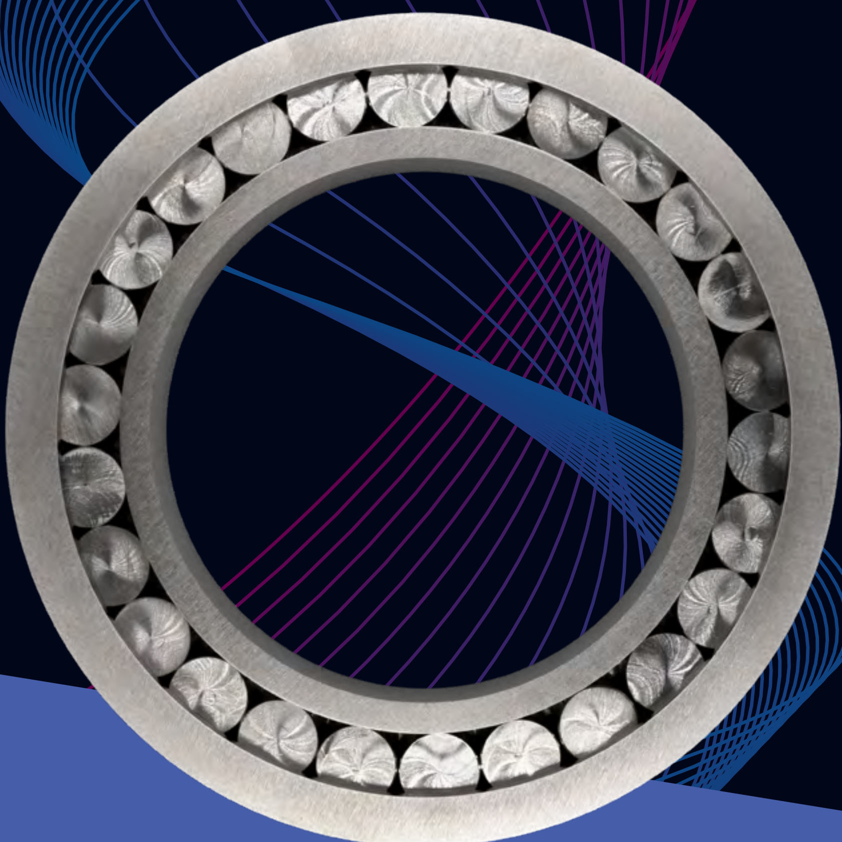
WHITEPAPER

Wire-Laser Hybrid Manufacturing

A Risk-Reduction Framework for Advanced Supply Chains



Prepared by Hybrid CNC Parts

With Phillips Additive Hybrid and Meltio technology

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Executive Summary

Organizations developing or sustaining high-performance metal components increasingly face a mismatch between application demands and what conventional manufacturing workflows can reliably deliver. Advanced alloys, complex geometries, and aggressive operating environments often drive long, multi-step supply chains, increasing exposure to extended lead times, late-stage scrap, and dependency on specialized external suppliers—at the same time that program schedules and qualification pressures continue to tighten.

Wire-laser hybrid manufacturing offers a practical solution to these constraints. By integrating metal additive builds and CNC machining within a single, controlled workflow, hybrid processes enable near-net parts to be produced and finished with fewer handoffs, reduced process complexity, and clearer accountability across manufacturing steps.

Hybrid manufacturing is not a replacement for conventional machining. Rather, it extends established machining practices with targeted additive capability—preserving dimensional control and inspection discipline while reducing supply-chain fragility and risk concentration in high-performance manufacturing programs.

This whitepaper explains:

- How wire-laser hybrid manufacturing integrates additive deposition and CNC machining into a single, production-ready workflow.
- Why conventional supply chains break down for high-performance metal components, particularly in low-volume, schedule-critical, or highly-regulated programs.
- How wire-laser hybrid manufacturing reduces supply-chain risk by addressing common issues such as long lead times, late-stage scrap, and fragmented traceability.
- Why disciplined documentation, inspection, and upfront part selection are essential to realizing wire-laser hybrid manufacturing's risk-reduction benefits in regulated environments.
- How a risk-based framework can be used to identify when wire-laser hybrid manufacturing is most effective, illustrated through use cases.

Introduction and Background

For advanced industries, manufacturing and procurement decisions extend beyond unit cost. Lead times, scrap rates, and supplier reliability directly influence program schedules and operational continuity. These decisions are fundamentally about risk—particularly for complex, low-volume, or first-of-kind components, where casting, forging, or tooling-dependent approaches can be slow, inflexible, or impractical.

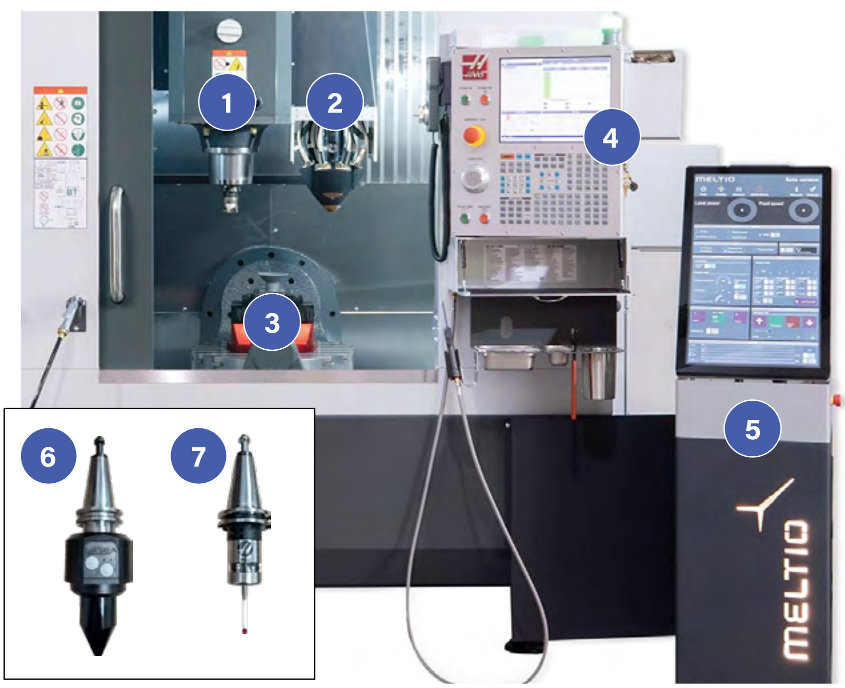
Wire-laser hybrid manufacturing has emerged as a practical response to these constraints. By combining additive metal deposition and CNC machining within a single, coordinated workflow, hybrid systems preserve machining-based control and inspection discipline while reducing reliance on long, fragile supply chains.

In this paper, the hybrid workflows described are implemented using Phillips Additive Hybrid systems with integrated Meltio wire-laser technology.

The Wire-Laser Hybrid Manufacturing Process

Wire-laser hybrid manufacturing integrates directed energy deposition (DED) and CNC machining within a single setup. Wire feedstock is deposited through a controlled laser melt pool to create near-net geometry, then machined in place to final dimensions and tolerances. Geometries and materials that are too complex, expensive, or difficult to work with conventionally are enabled using wire-laser hybrid methods, unlocking significant performance improvements.

This approach retains the control and inspection discipline of conventional machining while expanding material and design options beyond additive- or subtractive-only workflows.



1. CNC (Haas)
2. Deposition Head (Meltio)
3. Table (3- to 5-Axis)
4. Haas Controller
5. Meltio Laser Engine
6. Laser Marking Tool (Lase-X)
7. Inspection Probe

Figure 1. A Phillips Additive Hybrid wire-laser system, with Haas CNC and Meltio wire-laser DED technology. Insert: Lase-X Laser Marking Tool and inspection probe used in Hybrid CNC Parts' workflow. Photo © Phillips Additive Hybrid.

Problem: Conventional Supply Chain Failure

High-performance metal components often fail to transition smoothly from design intent to qualified hardware—not because the designs are flawed, but because conventional manufacturing supply chains are misaligned with the realities of advanced programs.

Traditional approaches rely on long, specialized supply chains that introduce extended lead times, limited flexibility, and irreversible process commitments that amplify the impact of late changes, scrap, and supplier delays. Tooling commitments, minimum order quantities, and lengthy qualification cycles further reduce responsiveness, particularly for low-volume, iterative, or first-of-kind components where schedules are tight and change is expected.

Standalone metal additive manufacturing alleviates some geometric and material constraints, but presents new challenges. Extensive post-processing reintroduces handoffs, variability, and cost—often eroding the schedule advantages that motivated adoption in the first place.

Across these conventional approaches, common failure modes emerge:

- Long feedback loops between design changes and physical parts.
- Elevated scrap and rework risk when deviations appear late in the process.
- Dependency on external suppliers with limited capacity or long lead times.
- Difficulty introducing advanced or multi-material performance without expanding cost and qualification scope.
- Fragmented traceability due to multi-vendor and disconnected manufacturing steps.

These challenges intensify in applications where performance, schedule, and reliability can not be traded off independently. In such environments, manufacturing constraints become program-level risks rather than operational inconveniences.

What is missing is a manufacturing approach that mitigates these risks while preserving proven machining practices and established qualification pathways.

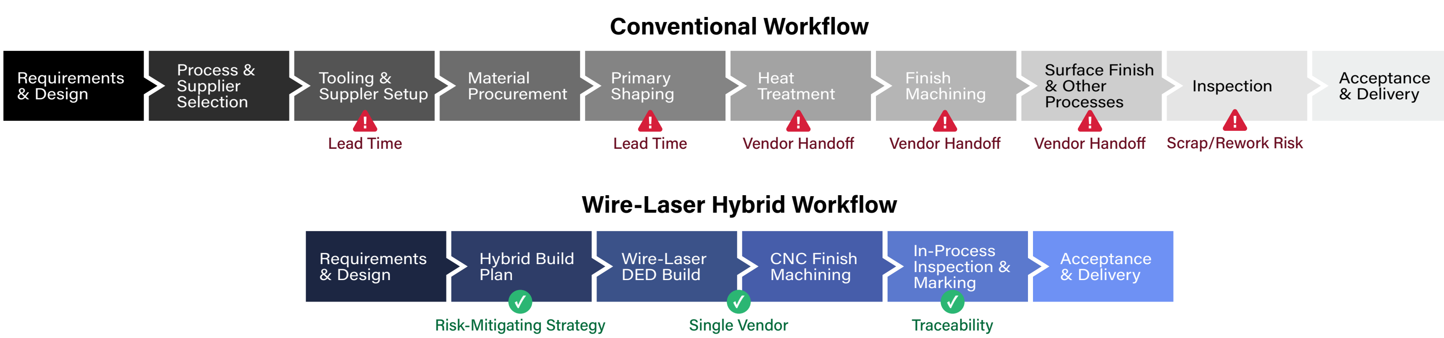


Figure 2. Comparison of conventional multi-vendor and wire-laser hybrid manufacturing workflows. Conventional workflows have multiple potential failure points, whereas a hybrid approach consolidates steps, preserves control, and reduces overall supply chain risk.

Solution: Wire-Laser Hybrid Manufacturing

Wire-laser hybrid manufacturing directly addresses the failure modes and associated risks that limit conventional and standalone additive approaches by consolidating additive and subtractive into a single workflow while expanding geometric and material options.

Rather than introducing a new manufacturing paradigm that must be qualified in isolation, hybrid systems extend established machining practices with targeted additive capability—reducing risk while expanding technical feasibility. Consistent with guidance from the NIST Manufacturing Extension Partnership, hybrid manufacturing reflects how organizations actually modernize: by extending proven processes while tightly managing qualification and operational risk.[1]

Risk Mitigation and Wire-Laser Hybrid Manufacturing

The critical risks associated with conventional methods are mitigated in several key ways using wire-laser hybrid manufacturing:

Compressed Lead Times

Near-net shapes built directly in the CNC reduce the number of external process steps between design and physical part. Design changes can be implemented, evaluated, and refined quickly, enabling rapid iteration without restarting long casting, forging, or tooling cycles (see Figure 2). Shorter lead times also reduce cost exposure by limiting idle capital, inventory holding, and the impact of schedule slips.

Reduced Scrap and Late-Stage Rework

Conventional manufacturing commits to material and geometry early, amplifying the cost of late-stage deviations or full-part scrap. In contrast, hybrid workflows are guided by Design for Hybrid Manufacturing (DfHM) principles that assess feature intent, material placement, stock allowance, tolerance strategy, inspection access, and finishing requirements upfront.

Greater Material Efficiency

In conventional manufacturing, material waste represents a disproportionate share of total part cost, particularly for high-value materials like titanium and superalloys.[2] Wire-laser DED enables controlled material placement near final geometry, limiting excess stock and reducing the volume of material removed during machining. In addition, billets can be retained as functional portions of the final part, further optimizing material use and downstream machining effort.

Reduced Handoffs and Consolidated Control

Manufacturing routes that rely on castings, forgings, or specialized tooling often involve long timelines and multiple vendor handoffs, any of which can become a failure point. Wire-laser hybrid manufacturing reduces handoff and conformance risk by consolidating building and finishing within a single, controlled workflow.

Viable Production Paths for Non-Standard and Low-Volume Components

Conventional manufacturing workflows are optimized for standard materials and high throughput, making specialized, low-volume, or first-article components difficult to accommodate. Wire-laser hybrid manufacturing supports flexible, near-net workflows that enable viable production paths for non-standard components while preserving a path to scale.

Increased Uptime Through Repair and Refurbishment

Component life can be extended and dependence on long-lead replacements reduced by restoring worn or damaged parts through targeted rebuilds using readily-available feedstock. Qualified designs are preserved, enabling critical equipment to remain operational through shortages, disruptions, or obsolescence.

Improved Performance Without Re-Qualification

Wire-laser DED supports selective placement of high-performance alloys only where needed, such as wear surfaces, thermal interfaces, corrosion-prone areas, or load-bearing regions. This approach delivers localized performance gains without triggering full-part material upgrades or re-qualification requirements.

Superior Traceability and Process Visibility

Process data is digitally captured during deposition, machining, and laser marking, improving documentation and traceability.

Reduced Cost-of-Delay Risk

In many advanced programs, the financial impact of extremely long lead times, schedule slips, or delayed qualifications outweighs marginal differences in per-part cost. By compressing the path from design to validation, wire-laser hybrid manufacturing allows teams to prioritize program continuity and reduced schedule risk over unit-cost optimization alone.

Wire-laser hybrid manufacturing reframes manufacturing from a series of fixed commitments into a risk-managed workflow. By reducing exposure across lead time, scrap, qualification, and supplier dependency, it enables organizations to pursue performance and schedule objectives without amplifying downstream risk.

Figure 3. A superalloy bearing at different stages of the wire-laser hybrid process: **(A)** near-net build of ring; **(B)** rings after wire-laser DED; **(C)** inner and outer rings after CNC machining; **(D)** assembled bearings with rings and rollers.

The following table summarizes common manufacturing risk drivers and demonstrates how wire-laser hybrid manufacturing alters their downstream business impact.

Table 1. Manufacturing Risk Drivers and How Hybrid Impacts Business Outcomes

Manufacturing Risk	Hybrid Impact	Business Outcome
Long lead times	Near-net shapes produced in-house without molds or dies	Faster first article; reduced schedule risk
Late-stage scrap or rework	Upfront process decisions guided by DfHM principles	Fewer late-stage surprises or full-part scrap
Excessive material waste in high-value alloys	Near-net builds with selective material placement	Lower material cost; improved capital efficiency
Increased risk of error with multi-vendor supply chains	Consolidated workflow	Reduced handoffs; improved quality control
Limited flexibility for specialized or low-volume components	Flexible, near-net workflows	Viable production paths for non-standard components
Downtime driven by long-lead replacement parts	Targeted rebuild or restoration of existing parts	Increased uptime; reduced dependence on replacements
Delays for qualification of new materials	Selective alloy placement	Performance gains without full re-qualification
Fragmented traceability	Reduced handoffs with single, coordinated workflow	Improved auditability; simplified compliance
Cost-of-delay greater risk than cost-per-unit	Compressed design-to-part cycles	Improved delivery confidence; lower program risk

Documentation and Inspection Protocols

Hybrid manufacturing reduces risk only when the process is controlled and documented. For regulated or high-consequence components, documentation and inspection are integral parts of the manufacturing deliverable.

To support qualification, failure analysis, and lifecycle management, Hybrid CNC Parts applies the following protocols to maintain control and visibility throughout the process:

Material pedigree: Certifications and heat/lot traceability for feedstock and base material.

Build strategy: Define where material is added, what is machined, and why.

Process records: Deposition and machining parameters captured as part of the job record.

Inspection gates: Defined checkpoints prior to final machining and before shipment.

Identification: In-process serialization or data-matrix marking when required.

Final verification package: Critical dimension results and quality documentation.

Implementation Considerations

Hybrid manufacturing is not positioned as a universal replacement for conventional processes. Its value is highest where performance requirements, schedule pressure, and supply-chain risk intersect—particularly for complex, low-volume, or first-article components. In these cases, hybrid approaches provide a practical way to expand design and material options while maintaining the control and predictability expected in advanced manufacturing.

Successful hybrid manufacturing programs begin with disciplined part selection and a clear qualification strategy. The objective is not broad substitution of conventional processes, but targeted use of hybrid methods where they meaningfully reduce risk, improve performance, or relieve supply-chain constraints.

The manufacturing risks summarized in Table 1 provide a practical lens for identifying where hybrid manufacturing is most effective in production.

Applications and Use Case Examples

The following examples apply the manufacturing risk framework developed earlier in this paper to real production scenarios, highlighting how wire-laser hybrid manufacturing addresses conditions where conventional workflows tend to concentrate risk—such as demanding environments, tight schedules, low production volumes, or elevated qualification requirements.

Specialty Components: Nuclear Bearings

Risk Profile: *Demanding environments, tight schedules, low-volume/specialized components, qualification requirements*

Next-generation nuclear systems present highly-corrosive environments with temperatures approaching 1,000°F, requiring components with exceptional material performance and dimensional stability.

Using DfHM principles, Hybrid CNC Parts optimized the use of high-performance alloys (Nickel 718, AWS 5.21 ERCoCr-A, and H11 tool steel) in creating small-batch specialty bearings.

Hybrid workflows enabled testing assets and production articles to be built in parallel, supporting rapid prototyping, first-article development, and in-process validation aligned with nuclear qualification requirements. Fully hardening H11 *in situ* reduced processing steps and external dependencies.

This approach addresses common risks associated with superalloy components and low-volume projects—namely long lead times, inflexible suppliers, material waste, and late-stage scrap—while maintaining qualification discipline.

Figure 4. Complete nuclear bearing with superalloy rings and rollers.

Targeted Material Performance: Sprue Bushing with Superalloy Core

Risk Profile: *Demanding environments, qualification requirements, lifecycle/maintainability concerns*

Injection molding environments impose extreme thermal and mechanical wear on tooling components, particularly at material interfaces. In this application, a sprue bushing was produced with an Inconel® 718 core for high-temperature and wear resistance, combined with a mild steel outer body optimized for machinability and cost control.

Wire-laser hybrid manufacturing enabled the creation of a solid, void-free, metallurgically bonded structure without separate joining operations. By confining high-performance materials to functionally-critical regions, this approach avoids full-part material upgrades and the associated qualification and cost escalation.

Figure 5. Multi-material sprue bushing produced using wire-laser hybrid manufacturing.

Schedule-Critical Components: Hydrogen Valves

Risk Profile: *Demanding environments, tight schedules, qualification requirements*

Liquid hydrogen systems operate at cryogenic temperatures (approx. −423 °F), where thermal contraction, material brittleness, and leakage risk impose stringent performance requirements. Components must maintain leak-tight operation across extreme temperature gradients, with failure leading to safety hazards or shutdowns.

In this example, an off-the-shelf brass valve was reverse engineered and optimized using 316 H stainless steel. The hybrid workflow enabled rapid progression from measurement to CAD to prototype and first article, while selectively reinforcing critical features such as the valve seat—without requiring a full redesign or re-qualification. Eliminating tooling delays and compressing the path from reverse engineering to validated hardware, this approach significantly reduces schedule risk.

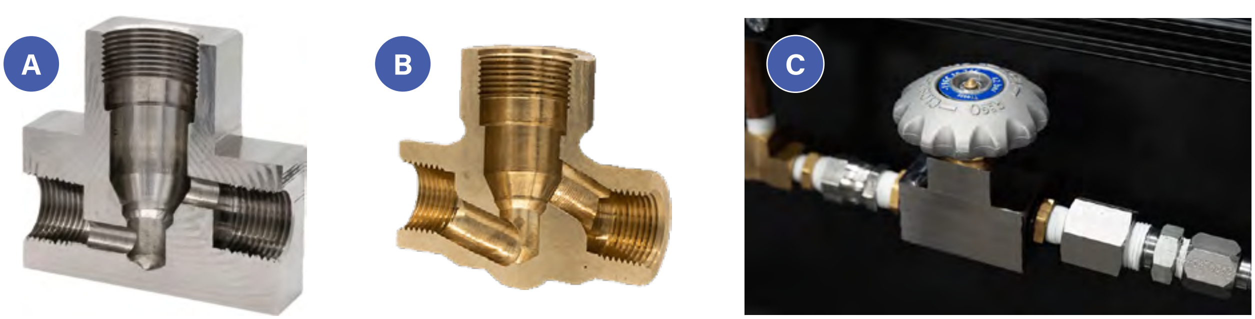


Figure 6. (A) Cross section of hybrid-manufactured liquid hydrogen transport valve; **(B)** original, reverse-engineered valve; **(C)** hybrid valve situated in test rig.

Functional Geometry: Serviceable Conformal Cooling Design

Risk Profile: *Downtime/replacement sensitivity, lifecycle/maintainability concerns*

Thermal management directly affects cycle time, part quality, and component life, but conventional machining limits cooling channels to straight-line drilling, while fully additive approaches often introduce inspection and serviceability challenges.

Wire-laser hybrid manufacturing enables complex, internal cooling geometries to be embedded where they deliver meaningful thermal benefit, while preserving machined surfaces and access needed for maintenance and refurbishment. This approach captures the performance advantages of conformal cooling without locking tools into fragile or inaccessible designs.

Figure 7. Conceptual design of a charge plate for industrial energy storage, with top interface layer removed. Inside are the topology-optimized flow channels, colored purple for Stellite® and blue for Inconel.

Conclusion

Hybrid manufacturing is best understood as a risk-reduction framework for high-performance metal components. By integrating additive near-net builds and CNC finishing into a single workflow, wire-laser hybrid manufacturing shortens lead times, reduces material waste, and enables targeted material performance while preserving traceability and quality control.

Rather than disrupting established practices, hybrid manufacturing extends proven machining workflows to better align with modern program realities—where advanced requirements can be addressed without amplifying program risk.

Evaluating Fit for Hybrid Manufacturing

If you're evaluating a component with long lead times, high scrap risk, or difficult material requirements, a short technical scoping discussion can help determine whether a wire-laser hybrid approach is a good fit.

Have available a drawing or CAD model, target material properties, critical features, inspection requirements, and any qualification constraints. The goal is to identify where hybrid reduces risk—and where it doesn't—before committing time or budget.

Contact

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About Hybrid CNC Parts

Hybrid CNC Parts is an advanced manufacturing firm specializing in wire-laser hybrid manufacturing. Established in 2021, it has quickly become a leading producer of precision components for demanding applications.

Hybrid CNC Parts is a fully-owned subsidiary of Multiscale Systems, Inc., a solutions-driven research and design firm integrating engineering expertise with precision manufacturing to solve complex, real-world challenges.

Co-located in Worcester, Massachusetts, Hybrid CNC Parts and Multiscale Systems deliver vertically-integrated design, engineering, and manufacturing capabilities under one roof.

Quality & Compliance

ISO 9001 & AS9100

NIST SP 800-171

DFARS 252.204-7012

CMMC 2.0 Level 2

Endnotes

1 Additive Manufacturing/3D Printing. 2022 Aug 10. NIST. https://www.nist.gov/mep/additive-manufacturing3d-printing.

2 Barriobero-Vila P, Gussone J, Stark A, Schell N, Haubrich J, Requena G. 2018. Peritectic titanium alloys for 3D printing. Nature Communications. 9(1). doi:https://doi.org/10.1038/s41467-018-05819-9.